From Newton's Cradle to Communication Using Natural Language:

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From Newton's Cradle to Communication Using Natural Language: Are Human Beings more Complex than Balls?

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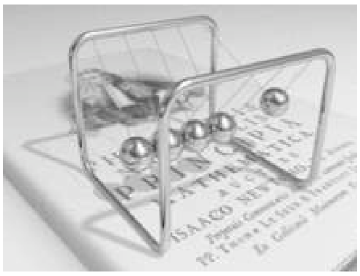
The simplest and best known models of interactions in classical mechanics are the ones which describe exchange of energy, of linear momentum or of electric charge between small macroscopic objects, such as balls. I will show that the set of principles classically used to account for what happens in Newton's cradle does not really account for what happens in Newton's cradle and that, moreover, it predicts possible behaviors that are never observable (this, obviously, is not an original contribution but the demonstration is not so old, is generally ignored in school books though it deserves being remembered, and will be useful for the purpose of this paper).

Simpler even is the model generally used when dealing with signal and its propagation; it is that model, however, that is almost universally used as a model of human communication. We will see some of the deplorable and piteous consequences of that carelessness on the way meaning is studied in linguistics and on the possible results of such studies. I will suggest a more serious, though more difficult, way to represent human communication and will examine its consequences on the linguistic approaches to describe the meaning of natural language expressions and account for the semantic phenomena.

1. From ball to balls: carelessness as a generalized intellectual system?

The simplest and best known models of interactions between material entities are the ones which describe exchange of energy, of linear momentum or of electric charge between small macroscopic objects, such as balls. Let us examine, for instance, the typical scenario of Newton's cradle, when only one of its balls is thrown, as illustrated in *Picture 1*.



Picture 1: a material realization of Newton's cradle[1]

The classical description of the observable interactions can be summed up as follows:

> "When the ball at one end is pulled aside and released it collides with the remaining stationary balls and the ball at the other end of the row moves off to reach what appears to be the same height from which the first ball was released. All the other balls are apparently at rest." [Gauld 2006: 597]

[1] Picture from file: Newtons_cradle_animation_book_2.gif, under free Creative Commons License. Author: Dominique Toussaint; date: 2006/08/08.

From this observation, many school books and didactic web pages (erroneously) conclude that "the effect of the collision simply consisted in the exchange of velocities between both balls"[2]. Considering the situation in which more than one ball is pulled and released allows to slightly better that conclusion, but, as we will see, not to correct it. The cases with more than one ball can be described as follows:

> If two balls are pulled aside and released, after the collision two balls move off – again apparently to the same height – with the rest stationary. Releasing three balls results in three balls moving off after the collision.

In those cases, clearly, velocity is not enough and school books are forced to introduce the notion of momentum conservation and, for some of them, that of energy conservation.

More precisely, the 'explanation' goes like this :

Ball A (system A) which was separated from the other four (B, C, B', A'), after being released, meets the remaining balls (system [BCB'A']), and transmits its momentum to the system [ABCB'A']. In the theoretical conditions of the experiment, it is assumed that there is no loss of momentum or energy. System [ABCB'A'] then transmits, energy and momentum to ball A' (opposite to A), which separates in turn; the system is thus in a position symmetrical to the initial situation, in which A' plays the role of A and vice versa.

However, this reasoning does not explain why A' moves off alone (and, more generally, why the number of balls which move off after collision is equal to the number of balls which provoked collision). Gauld (2006) reveals an interesting but rather startling fact connected to this lack of explanation: none of the 40 scholar books he studied considers that question as requiring an explanation…

> "About one third of about 40 tertiary physics textbooks sampled contained some reference to Newton's Cradle […] However, it is interesting to note that, in spite of the apparent simplicity of the demonstration, the behaviour of Newton's Cradle is not adequately explained in these textbook presentations *and there may not even be a fully adequate explanation available in the physics education literature*."
>
> [Gauld (2006): 598); my emphasis]

Gauld wryly adds, further on:

> "One might excuse teaching which is ignorant of little known facts but it is less easy to excuse facts about the apparatus which are more easy to establish such as that the principles of conservation of momentum and kinetic energy are not sufficient, in themselves, to explain the behaviour of Newton's Cradle." [*ibid.* p. 615]

And this enormous cheating (if we may so call what Gauld pointed out) was so, in 2006, in spite of the fact that Herrmann & Schmälzle (1981) had shown that the use of the two usual conservation principles (momentum and kinetic energy) is not sufficient to describe the facts observed.

For instance, in the case of an initial impact with one ball (A), energy and momentum conservation would not prevent that A bounced with a speed equal to one third of the initial velocity, while A' and B' separate with a speed equal to two thirds of the initial velocity of A.

Indeed, as Herrmann & Schmälzle (1981:762) develops:

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[2] Translated from the French Wikipedia page on Newton's Cradle: https://fr.wikipedia.org/wiki/Pendule_de_Newton (still visible on December 30th 2013).

"Imagine now the following final state: ball 1 moves to the left with $v = (-1\ /3)v_0$, balls 2 and 3 move to the right, both with the same speed $v = (2/3)v_0$. It is easy to confirm that the values of the kinetic energy and the momentum of this hypothetical final state are the same as those of the initial state:

$$Ek = (1/2)m[(1/3)v_0]^2 + 2(1/2)m[(2/3)v_0]^2$$
$$= (1/2)mv02,$$
$$P = m[(-1/3)v_0] + 2m(2/3)v_0$$
$$= mv_0.$$

Thus energy and momentum would be conserved. Nevertheless, the actual experiment always evidences another outcome."

The following fanciful illustration gives an idea of the possible (but not actual, of course) behavior of the cradle when applying only momentum and kinetic energy conservation principles.

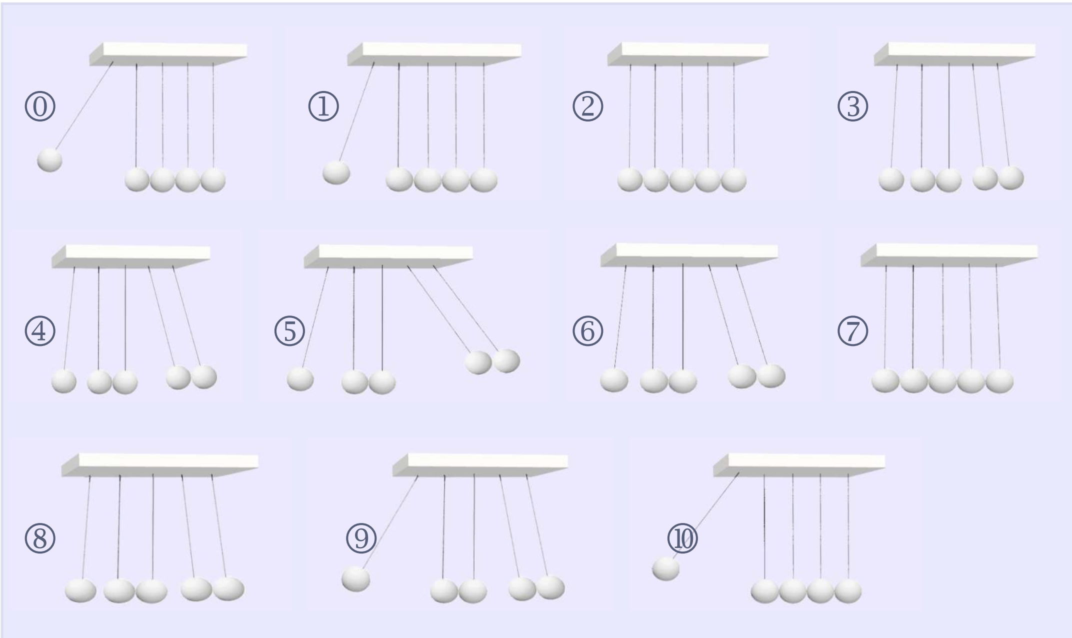
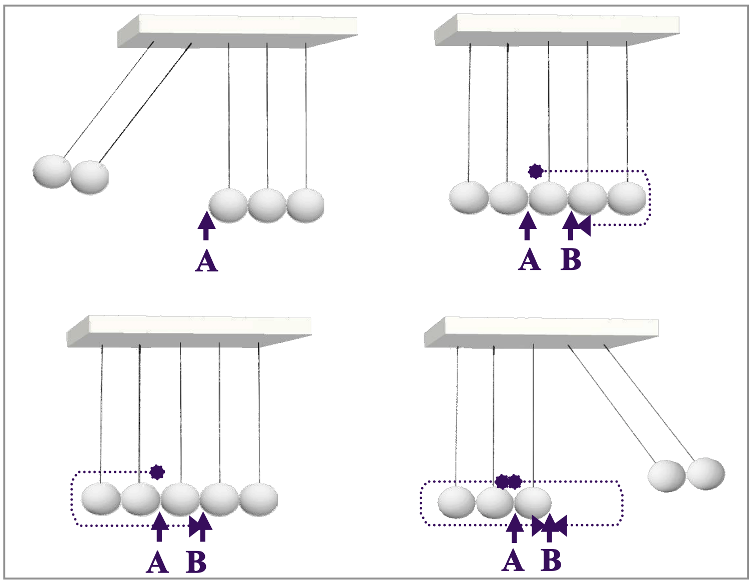


Illustration 1: fanciful non-actual behavior of cradle (compatible with the classical explanation)

Since that behavior was never observed, there must be another constraint which the cradle must satisfy.

Herrmann and Schmälzle (1981:763-764) argue that "In a non-dispersion-free system, energy and momentum are distributed throughout the entire arrangement.", while what we observe is that the total energy and momentum of the incoming balls is transferred to the same number of balls at the other end of the chain. They thus propose a simple explanation involving a third conservation principle, shock wave energy conservation, allowing the kinetic energy transmitted by A to [ABCB'A'] to be transferred without loss to A', through the initial shock wave. This constraint allows to take into account the propagation of the double perturbation wave due to the initial shock, perturbations which travel across the system in each of the two directions, and move backwards after reaching the system ends, *without attenuation*, and therefore, at the same speed. It is at the point where the two wave packets meet that the balls separate; this point must be symmetrical to the point of impact in order for the two wave packets to travel the same distance before they meet. The following schema illustrates this point:



Schema 1: explanation using the (additional) dispersion-free constraint

Extremely reassuring and fresh did I thus feel the proposal presented in 2010 by a group of secondary school students to the French Physics Olympiad, and… primed with the first prize. For they address that specific problem in a way that is both correct and amusing, and propose a solution which is both amusing and… correct.

Nicolas BELIAEFF, Romain HEIMLICH and Baptiste JEANIN, from the Lycée Jean Eiffel (Dijon, France), formulate their conception of the problem in this way:

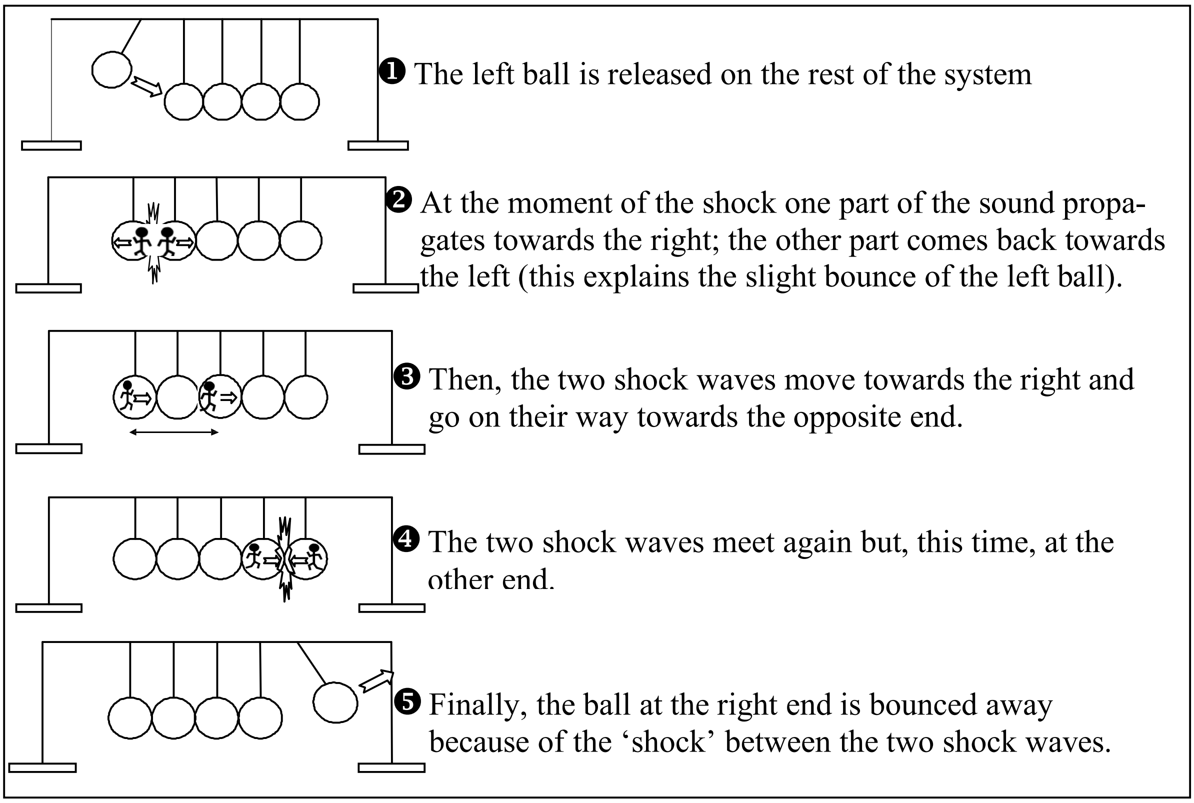
> « [Nous] nous sommes alors demandés comment la dernière bille, qui n'a pas assisté au cours de physique, a pu savoir qu'elle devait conserver énergie cinétique et quantité de mouvement. »
>
> "[We] then wondered how the last ball, which did not follow the physics class, could know that it was supposed to preserve both kinetic and momentum"

[Beliaeff *et al.* (2010)]

And they immediately propose a hypothetic answer, the validation of which is the object of their exposition:

> « Nous avons alors supposé que ces informations devaient être envoyées par la première bille et que le son ou la vibration due au choc devait contenir ces informations. »
>
> "We then made the hypothesis according to which this information was sent by the first ball and that sound or vibration due to the initial shock should contain this information" [*ibid.*]

I cannot resist the temptation to show the way in which this hypothesis is discussed and illustrated in their work, where *ludic* goes together with *lucid, and 'ludicity*' seems to be a real warrant for *lucidity*… a brief sequence of schemata, with their comments, will be enough to give an idea and, I hope, the intellectual pleasure.



Schema 2: explanation using the hypothesis 'sound as a messenger' (adapted from Beliaeff et al. (2010))

2. From balls to Human Being: the… *impact* of communication

The standard communication model used for signal processing, since Shannon (1948) and Shannon & Weaver (1949), can be summarized in the following proposition

> A *sender* encodes a message and emits the result of the encoding towards a *receiver*, which perceives it in an environment possibly disturbed by other transmissions (noise), and then performs the decoding.

That conception of signal transmission allowed to give an operational definition of *information*: *information*, within signal study, is the inverse of noise[3].

The communication model underlying that important work on signal was 'sold' to linguistics, though it was intended only for signal[4]. Roman Jakobson (1960) did feel the model was insufficient to account for human verbal communication but believed that, with a few 'patches'[5], it could be used as a first approximation. A version of Shannon and Weaver's signal model, 'patched' by Jakobson and simplified 'for didactic purposes' (henceforth: STD) is still constantly taught as *the* model of human communication 'discovered' by Jakobson…

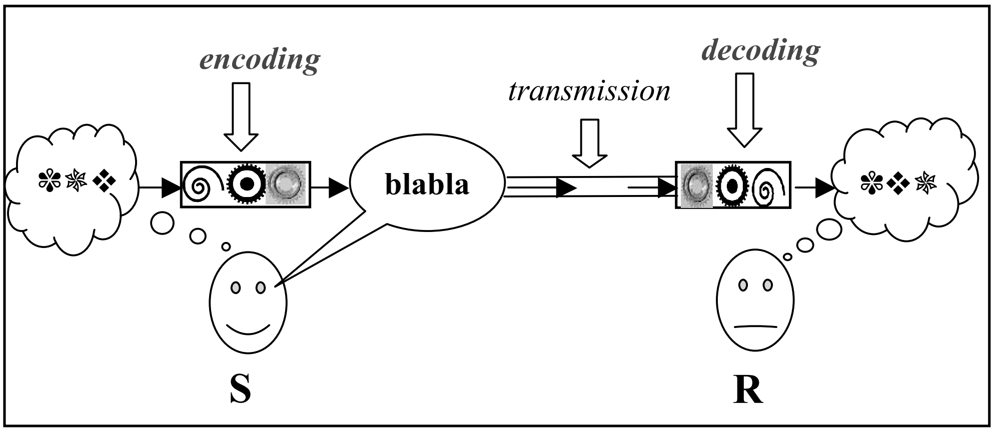
Paying attention to the structure of the signal treatment diagram (STD), as it is adapted for human communication (with 'patches' and 'didactic' simplification), one easily realizes that it

[3] Several cynical theorists argue that that is the reason why the century turn, with its ubiquitous glorification of public communication, has drowned information in an ocean of noise; in particular in the realm of scientific research, where the commandment "Publish or perish!" engulfs genuine scientific information in a tsunami of noxious waffle…

[4] It seems that the 'transaction' was done in spite of Shannon's doubts, for whom the signal model is not proper for anything else than signal.

[5] *Cf.* the six famous functions of languages he introduced in Jakobson (1960), and which are taught in practically all the classes of linguistics in France.

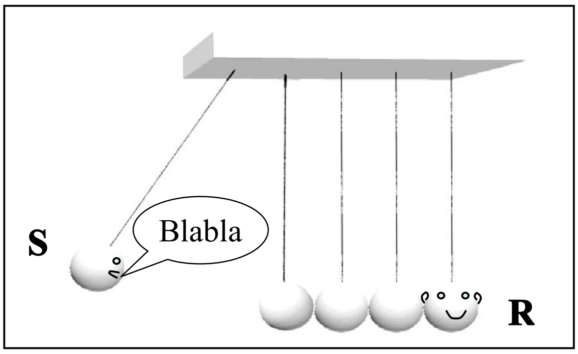
is even simpler than the one which does not work for Newton's cradle. The following schema illustrates the model in question.



Schema 3: STD – an adaptation of the signal model *to human linguistic communication*

For linguistic studies, the transmission process is not an object of study; on the other hand neither the encoding and decoding processes, nor the original and 'reconstructed' messages (illustrated here by compositions of ✾,❃ and ❖) are observable… However, as any linguist is as good a speaker as any other speaker (which is certainly true), most of the linguists (mistakenly) consider that the non-observability of the processes, of the original message or of the 'reconstructed' message poses no problem: from the output of the sender, the linguist '*knows*' the message he/she (the sender) encoded; and, at the same time, '*knows*' what the receiver will get when decoding the transmission and 'reconstructing' the message[6]. The discussion of this magic belief is not the subject of this paper[7] and I sufficiently suggested what I think of it (for some, even too much…): I only intend to show, here, that (independently of its magic touch) the model in question, STD, is a caricatural simplification of the one that does not work for Newton's cradle and, as such, is not likely to work for more complex interactions, such as human linguistic communication.

If we want to merge the description of what happens in Newton's cradle and the description of what, according to STD, happens in human linguistic communication, we get something that may look like schema 4:



Schema 4: a cradle-like approach to the signal-like model of human communication

where the impact of ball S corresponds to the transmission of the encoded message through the three balls in the middle, and the separation of ball R corresponds to the result of decoding

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[6] This would seem absurd to any other researchers and, probably, to any other human being; but not for most linguists.

[7] For elements of that discussion, see, for instance, Raccah (2005), Raccah (2011a), or Raccah (2011b: 154-161); those who read Russian can find in Raccah (2011c) a few proposals for a linguistic experimental approach to semantics.

the received encoded message. However, when observing the cradle, the separation of ball R *is* observable (and the properties of that separation –momentum and amplitude– *are* measurable), while, when observing human communication from the point of view of STD, as we saw it in the preceding paragraph, what R understands, which corresponds to the separation of the ball, *is not* observable. In addition, in the cradle, what caused the impact *is* also observable and its properties measurable, while, in the signal approach to human communication, again, what precedes the emission of the encoded message *is not* observable (let alone measurable).

To make a short story short, the scheme of human communication based on the signal model (STD) does not predict anything empirically observable: it cannot, thus, account for anything that would not be believed in advance (in particular, it does not say anything about how meaning or *what* meaning is constructed by the recipient); and, of course, it is immunized against scientific refutation.

In the next section, I will discuss several properties a model for human communication should show and, as a conclusion, I will propose a model of linguistic interaction which does show these properties and does not suffer from the weaknesses of STD.

3. From Human Being to Human Being: the… impact *on* communication

Regardless of nonsensical but abundant literature bad uses of good but limited models produce, there are

(i) observable entities which are transmitted from S to R in a human communication between them (excluding meanings, intentions or messages), and

(ii) possible observable reactions by R (excluding what R understood), which may allow an observer to produce hypotheses about how R understood S's communicative move.

Moreover,

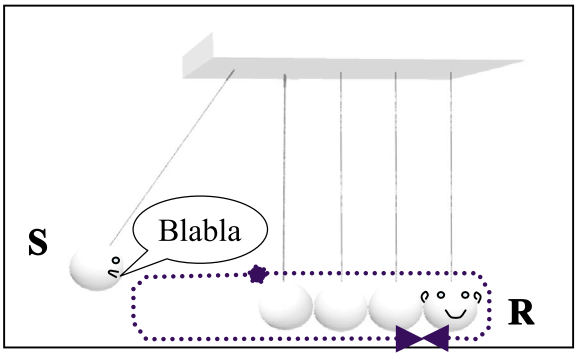
(iii) a sufficiently large set of interaction instances *necessarily* gives the cues which allow to grasp the semantic rules of a human language; this is so because any dunce can acquire, *and does acquire*, a human language in 18-24 months, being exposed only to speech and human attitudes.

In addition, an acceptable conception of human communication has to take into account other problems that could not even be conceived within STD:

1. In human linguistic communication, the meaning of what the 'sender' is about to say is accessible to *no one* (not even him(her)self) before (s)he speaks[8].
2. If *sound* is transmitted indeed (like in the school students conception of the cradle), meaning is not: it is constructed by the 'receiver' (in particular, on the basis of the stimulations that that sound occasioned).
3. Understanding a discourse (or any utterance of a human language sequence) does not involve encoding or decoding[9]
4. Understanding a discourse (or any utterance of a human language sequence) is an irrepressible and unconscious activity[10].

[8] *Cf.* Raccah (2008): 72-75.
[9] See Rastier (1995), Raccah (1998), and/or Grillo (2003).
[10] See Bruxelles *et al.* (1992).

If we go on exploring what is beyond the sole signal, it is clear that what S transmits to R (sound), (a) S too perceives it, (b) R (sometimes) reacts to it, (c) S too (sometimes) reacts to it, (d) S reacts to what she/he perceived of R's reaction, etc. The picture, thus, looks much more like the playful approach of the cradle, as presented by the high school students (with something running in both direction) than like the static simplification of the 'linguistic' model based on the *signal model.* Scheme 5 is an attempt to include these considerations into scheme 4:



Schema 5: schema 4 with feed back loop

The difficulty we underlined in the last section, the fact that *reactions* are not necessarily directly observable (in particular, *what is understood* by R is not directly observable), is not solved but, here, it is not hidden: R's reaction is present in the schema, and the experimentalist semanticist must design experiments which will allow to indirectly observe these reactions. The inclusion of the sort of feed-back loop in the presentation of what happens in communication allows to avoid two incredible mistakes, due to STD, which are quite often present in the implicit background of semantic work:

1. Discourse meaning, that the semanticist indirectly observes, and that will help him/her describe sentence meaning, is not the one (s)he him(her)self built, but one (s)he can show that this is what the receiver constructed: the last one requires arguments, while the first is based solely on intuition.
2. In order to be in the position to make (and argue) the hypothesis that the 'receiver' built utterance meaning S for discourse D, in the situation *i*, it is necessary to take into account the reactions of said 'receiver', and make abductive testable hypotheses about discourse meaning, which could explain these reactions.

Verbal reactions of R are not to be favored: they require interpretation by the semanticist, and thus introduce subjectivity in his/her observation. In the lack of better empirical material, one can be happy with them for a first approximation. However, this subjectivity regards the same area of research that we want to scientifically explore: there might soon be biases and conflicts of interest...

4. As a conclusion: a proposal for a model of human communication

We saw that the conception of human communication, STD, implicitly or explicitly used by most linguists all over the world is a simplified version of the model used for the treatment of signal. We also saw that that model is a simpler model of interactions with respect to the one mistakenly used to account for what happens in Newton's cradle: in addition to momentum and kinetic energy conservation, another principle is needed, namely what I called the *shock wave energy* conservation principle. I showed that the communication model STD, derived from the signal model, could make no empirical prediction, and I pointed out that several of its implicit assumptions are erroneous. I suggested that, modifying those assumptions implied a radical change in the conception of human communication, and adding an analogue of the shock wave conservation principle (which allows to take feedback into account) could yield to a much more interesting conception of human communication.

If I convinced the reader, I could be satisfied, even though one might argue that criticizing is easier than proposing… Luckily enough, I do have something to propose, which stems from all that critical work: a conception of *human communication using language*, which proceeds from a more general Communication Activity Representation conception (CAR). One of the advantages of this conception (from the point of view of the present paper) is that it does use the reflection developed here about Newton's cradle and the contrast between what is observable (for instance, the separation of the last ball) and what we use in order to account for it (principles), which is not observable. Another advantage (which might appear, at first, as an inconvenient) is that, once the proposal is understood, it seems to be so evident that it becomes difficult to envisage it as a real original conception of communication. This characteristic is an advantage because any move that is done to defend the idea that the said conception is too obvious to be a real original proposal is, *ipso facto*, an evidence in favor of that conception…

The proposal, called the *Manipulatory Conception of Human Communication Using Language* (in short, MCC) is the following:

> *When S communicates with R, S manipulates R to get*
> *R to construct the meaning S wants R to construct*

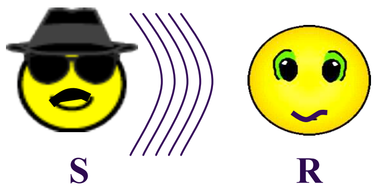


Illustration 2: MCC, in short

The sounds emitted by S do not carry meaning, but act on R to make R construct a specific meaning for S's utterance. The meaning R will create is, as we said, influenced by S's utterance, but also depends on R's knowledge and beliefs: what S produces (S's utterance) functions as a set of instructions which R carries out or implement, and which have the effect of making him/her build this specific sense. R's internal process is not conscious: obviously, R may build an *a posteriori* picture of 'what happened' in his/her mind, but the understanding process is not accessible while it takes place. The process itself is not directly observable: no one can access such internal processes (and, as we just saw, not even the person in which it takes place), but, sometimes, the outcome of the process provokes observable facts, which can be used to formulate abductive hypotheses about some aspects of the process. The process of meaning construction is also irresistible: the state of being a speaker of some natural language *forces* to understand any understandable utterance using that language.

For instance, about one half of the Anglophone American citizens might feel uncomfortable when hearing the following utterance:

> John Doe is a Republican but he is honest

This is so because the hearers cannot understand the utterance if they do not –at least provisionally, during the time of the process– accept that there is some kind of opposition between being a Republican and being honest. Interestingly enough, the other half (if we except the few semanticists that might belong to it) usually do not even notice that they have to accept such a point of view on Republicans: the semantic instruction acts unconsciously and irresistibly until it eventually leads to a point of view which is inconsistent with the hearer's. When this contradiction does not occur, there is no reason for the hearer to be conscious of all the points of view (s)he had to accept in order to understand. When the contradiction does occur, the hearer often feels aggressed: for good reasons since (s)he has been forced to accept (even provisionally) a point of view which (s)he does not share.

What has just been said about the oral modality is relevant, with very little changes, for written material. This might surprise because oral and written material differ in nature: each time one reads a written segment, (s)he produces a new utterance, different from one produced by another reading, and which is usually treated as new oral material (a sort of *inner voice*). However biologically different might be the initial effect of real sound input from the more abstract effect of a reading, one of the very interesting properties of human language processing is that, at the level of complexity of semantic treatment, they should not, and *cannot*, be differentiated: as far as meaning assignment for natural language expressions is concerned, no distinction is to be made between *inner* voice and *outer* voice. This astonishing property, which is characteristic of a separate scientific field for the study of language, is certainly related to the level of abstraction at which the complex processes of understanding take place; it does deserve more investigation, but this aspect of the question is both outside the domain of researches on language as such, and outside the reach of the present work: we will have to limit ourselves to signal the question.

Although MCC is too general to be a model, it may yield to sound models of human communication, grasped through its interactive aspect (as we saw in section 2, this is not true about the conception based on STD): in MCC, there is an observable input (sound or written material) and there may be observable outputs (reactions), in such a way that the non directly observable intermediates (meanings, representations, points of view, beliefs, etc.) can be indirectly observed, in a way analogous to how momentum, for instance, can be indirectly observed. The relationship between the added value of MCC and the correct account for Newton's cradle is the fact that, in MCC, S knows whether his/her action on R succeeded by interpreting R's reactions: the global effect of the interaction lies thus on the meeting point between the two actions packets.

Clearly STD and MCC are two incompatible competitive CARs. Now why should you buy the new CAR I propose? The first reason is, obviously, because your old CAR is out of order… More seriously, STD blocks the evolution of the accounts of human communication and of human language semantics because the oversimplified concepts it uses presuppose, as we have just seen, facts about communication and about language that we now know wrong. It may have been useful when the tracks leading to findings about human languages were narrow; but the map of knowledge on this subject has evolved since that time and you should not use your old CAR in the expressways that are available for scientifically exploring this territory.

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